HELPING *INDUSTRY* TO USE IT'S EYES

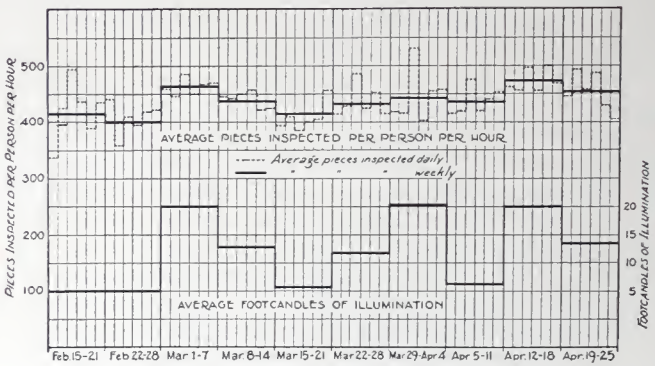
When workpeople can see easily . . . . . they do more and better work

LIGHT is a tool for seeing and seeing enters into practically every physical and mental act in the productive process. Yet this basic tool of all industry is still so imperfectly understood that seven out of ten industrial establishments are failing to provide lighting that is adequate for efficient seeing in the productive processes upon which these industries depend for profit.

The purpose of this booklet is to make clear to the practical executive how recent research on the subject of lighting, as related to seeing, is of fundamental interest and importance to industry.

The factors that make a lighting system adequate for seeing, and consequently for efficiency in production, reduced spoilage, lessened accident rate and improved morale, are set forth simply and understandably in following pages.

The difference between seeing and groping while at work . . . . .



WITH the object of determining exactly the influence of lighting upon production there have been numerous, extended experiments carried out in typical industries.

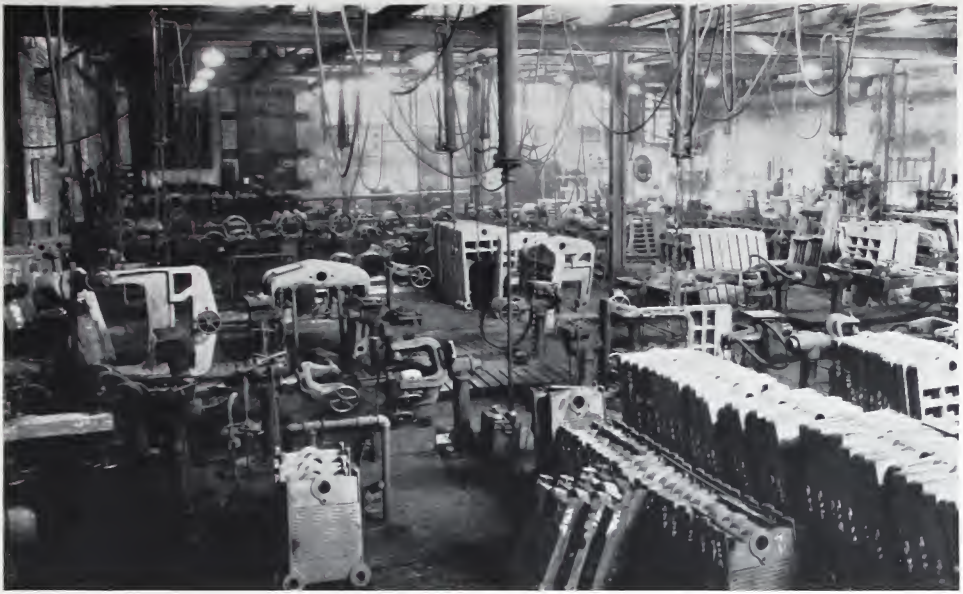
The experience summarized in the graph above covers ten weeks. For two weeks a group of some 40 workers in an inspection department were observed under the existing lighting system, which provided 5 foot-candles. Then the illumination was increased to 20 foot-candles with an immediate gain of 12½ per cent in output. Reducing the illumination to 13 foot-candles was followed by a drop in output, though this remained 8 per cent above the original. Going back to 6 foot-candles, the average output per worker declined, but still represented a gain of 4 per cent. A graph shows the illumination was stepped up and then down successively and in every instance the rate of productiveness rose or fell accordingly, proving that there was a definite relation between the ease with which workers could see and the amount of work performed.

Note that an increase of 4 per cent in output was obtained by increasing light only one foot-candle. This result was due, however, largely to the elimination of glare and specular (mirror-like) reflection.

At 20 foot-candles the increase in production, amounting to 12½ per cent, was obtained at an increased cost for lighting which amounted to less than 2½ per cent of the payroll.

In a 15-month test at the plant of the Detroit Piston Ring Co., a 25 per cent increase in production per employee was brought about by raising the illumination from 1.2 foot-candles to 18 foot-candles, at a cost amounting to only 2 per cent of the payroll.

Researches have now established beyond doubt that seeing is not a simple, instantaneous act, but always involves a time element. Furthermore, all human eyes



View in the American Radiator Company's Buffalo plant, after relighting to modern standards. Note absence of glare and deep shadows.

are not alike—possibly 50 per cent of all workers have defects of vision unknown to themselves or their employers—so that a standard of lighting that permits reasonably easy seeing for normal eyes may be far too low for easy seeing by workers with even slight defects of vision.

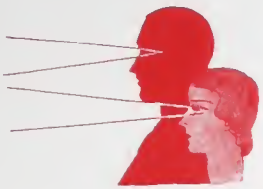
In the table following are summarized several other typical instances of the astonishing gains made possible by improved lighting.

What Efficient Illumination Will Do

Kind of Work	Foot Candles		Increase in Production
	Old	New	
Stamping and Pressing	0.7	13.0	12.2%
Semi-automatic Buffing	3.8	11.0	8.5%
Iron Pulley Finishing	0.2	4.8	35.0%
Soft Metal Bearings	4.6	12.7	15.0%
Heavy Steel Machining	3.8	11.0	10.0%
Carburetor Assembling	2.1	12.5	12.0%
Spinning (Textile Mill)	1.5	9.0	17.0%

THE illustrations on this page show graphically how much improvement can be made in an installation that was believed to be adequately lighted. Both photographs were taken in the Packard Motor Car Company plant, Detroit. On account of the low ceiling, additional light had to be obtained by increasing the number of lamps instead of their size. Note (in the illustration below) how close to the ceiling the new lamps are mounted and how greatly general illumination has been improved as well as illumination along the assembly chain.

What constitutes an adequate system of lighting for seeing?



WHILE the actual specifications for a good lighting system in any specific case should be worked out with the help of a lighting specialist, the general principles which determine whether or not an existing system approximates the desirable standard, can be stated quickly. These are: Enough light properly delivered at all working points to avoid glare and shadow and to permit the speed and clearness of discrimination upon which rest productive efficiency, safety and minimum of fatigue.

It is almost universally true that modern standards of acceptable industrial lighting call for levels of illumination several times higher than are usually found, but it is also true that intensity is only one factor in good seeing.

1
Amount of light at the work

In almost any type of manufacturing processes 12, 15 or 20 foot-candles can be profitably used. For fine work and for close or fine inspection 25 foot-candles are justified by results. On the next page there will be found a table of foot-candle standards for many of the commoner kinds of work.

2
Freedom from glare and shadow

The proper distribution of light is at least as important as the general level of illumination. Glare is of two kinds: that which enters the eye directly from the light source, and that which is reflected from brightly polished or highly reflecting surfaces. Many existing lighting systems could be made far more efficient by simple changes in the location and type of lamps and reflectors without increasing the wattage consumed.

3
Maintenance factors

Maintenance is as important for productive lighting as the design of the lighting system itself. Dark or dirty surfaces absorb light. Keep these surfaces clean and light in color. Keep lamps and reflectors clean. Replace blackened lamps. Lamps burned below normal voltage do not give their rated amount of light.

A check list of accepted minimum standards for industrial lighting . .

	Foot-Candles Recommended	
	Good Practice	Minimum
Assembling:		
Rough	8	5
Medium	12	8
Fine	20	12
Extra Fine	50–100	25
Automobile Manufacturing:		
Automatic Screw Machines	15	10
Assembly Line	15	10
Frame Assembly	12	8
Tool Making	20	12
Body Manufacturing—Assembly, Finishing and Inspecting	50–100	25
Bakeries	12	8
Book Binding:		
Folding, Assembling, Pasting, etc.	8	5
Cutting, Punching and Stitching	12	8
Embossing	15	10
Candy Making	12	8
Canning and Preserving	12	8
Cloth Products:		
Cutting, Inspecting, Sewing—Light Goods	15	10
Dark Goods	50–100	25
Pressing, Cloth Treating (Oil Cloth, etc.)—Light Goods	12	8
Dark Goods	20	12

	Foot-Candles Recommended	
	Good Practice	Minimum
Electric Manufacturing:		
Storage Battery, Molding of Grids, Charging Room	10	6
Coil and Armature Winding, Mica Working, Insulating Processes	20	12
Elevator—Freight and Passenger	8	5
Forge Shops and Welding	10	6
Foundries:		
Charging Floor, Tumbling, Cleaning, Pouring and Shaking Out	8	5
Rough Molding and Core Making	10	6
Fine Molding and Core Making	15	10
Garage—Automobiles:		
Storage—Dead	3	2
Live	8	5
Repair Dept. and Washing	15	10
Inspecting:		
Rough	10	6
Medium	15	10
Fine	25	15
Extra Fine	50–100	25
Polished Surfaces	Usually requires glint reflections from specially located light source	

	Foot-Candles Recommended	
	Good Practice	Minimum
Laundries and Dry Cleaning	12	8
Machine Shops:		
Rough Bench and Machine Work	10	6
Medium Bench and Machine Work, Ordinary Automatic Machines, Rough Grinding, Medium Buffing and Polishing	15	10
Fine Bench and Machine Work, Fine Automatic Machines, Medium Grinding, Fine Buffing and Polishing	20	12
Extra Fine Bench and Machine Work, Grinding (Fine Work)	50–100	25
Offices:		
Private and General—		
Close Work	15	10
No Close Work	10	8
Drafting Room	25	15
Packing:		
Crating	6	4
Boxing	10	6
Paint Shops:		
Dipping, Spraying, Firing	8	5
Rubbing, Ordinary Hand Painting and Finishing	12	8
Fine Hand Painting and Finishing	15	10
Extra Fine Hand Painting and Finishing (Automobile Bodies, Piano Cases, etc.)	50–100	25
Power Plants, Engine Rooms, Boilers:		
Boilers, Coal and Ash Handling, Storage Battery Rooms	5	3
Auxiliary Equipment, Oil Switches and Transformers	8	5
Switchboard, Engines, Generators, Blowers, Compressors	10	6
Printing Industries:		
Matrixing and Casting, Miscellaneous Machines, Presses	12	8
Proof Reading, Lithographing, Electrotyping	15	10
Linotype, Monotype, Typesetting, Imposing Stone, Engraving	50–100	25
Shoe Manufacturing:		
Hand Turning, Miscellaneous Bench and Machine Work	12	8
Inspecting and Sorting Raw Material, Cutting, Lasting and Welting (Light)	15	10
Inspecting and Sorting Raw Material, Cutting, Stitching (Dark)	50–100	25
Textile Mills:		
(Cotton)—		
Opening and Lapping, Carding, Drawing-frame, Roving, Dyeing Spooling, Spinning, Drawing-in, Warping, Weaving, Quilling, Inspecting, Knitting, Slashing (over beam end)	8	5
	12	8
(Silk)—		
Winding, Throwing, Dyeing	12	8
Quilling, Warping, Weaving and Finishing—		
Light Goods	15	10
Dark Goods	20	15
(Woolen)—		
Carding, Picking, Washing and Combing	6	4
Twisting and Dyeing	10	6
Drawing-in, Warping—		
Light Goods	10	6
Dark Goods	15	10
Weaving—		
Light Goods	12	8
Dark Goods	20	12
Knitting Machines	15	10
Tobacco Products:		
Drying, Stripping, General	3	2
Grading and Sorting	25	15
Woodworking:		
Rough Sawing and Bench Work	8	5
Sizing, Planing, Rough Sanding, Medium Machine and Bench Work, Gluing, Veneering, Cooperage	12	8
Fine Bench and Machine Working, Fine Sanding and Finish	15	10

Outdoor illumination ranges from several hundred to several thousand foot-candles—and nobody thinks it too bright.

The composing room of a large publishing company before relighting.

Note absence of glare and shadow as compared with same room shown above.

Outdoor laborers get 100 times as much light as skilled workers indoors . . .

ON a cloudy day the level of illumination outdoors can be as high as 1,000 to 1,500 foot-candles. In midday summer sunshine the intensity of light reaches 10,000 foot-candles, or 5,000 times the intensity of illumination in many warehouse and even factory interiors!

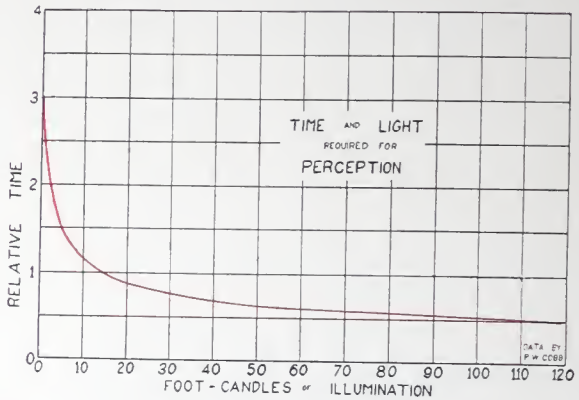
The human eye as an optical instrument has developed under natural daylight and is therefore adapted to light intensities far higher than any created artificially. Provided the light comes from overhead and is evenly diffused, intensities of 100, 200 or 1000 foot-candles are not fatiguing to the eye.

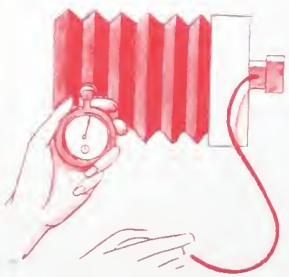
It is glare, intense light shining or reflected directly into the eye, which is harmful and dangerous.

Outdoors, light is uniformly distributed. Except when looking upwards into the sky, there is little or no necessity for adjustment of the pupil to accommodate for differing intensities, and thus there is little or no eye strain.

Indoors, on the other hand, the intensity of illumination may drop from 100 foot-candles near the window to as little as three or four foot-candles twenty or thirty feet away, and this even in modern factories.

Poor light forces the eye to take time exposures instead of snap shots . . .





THE human eye, though it is very much more sensitive than any photographic plate so far invented, is nevertheless far from instantaneous in action. Every act of seeing involves some time. The least amount of time required by the eye to fixate and recognize details, as for example in reading, seems to be 0.075 second. From this the time ranges up to 0.3 second or four times as long.

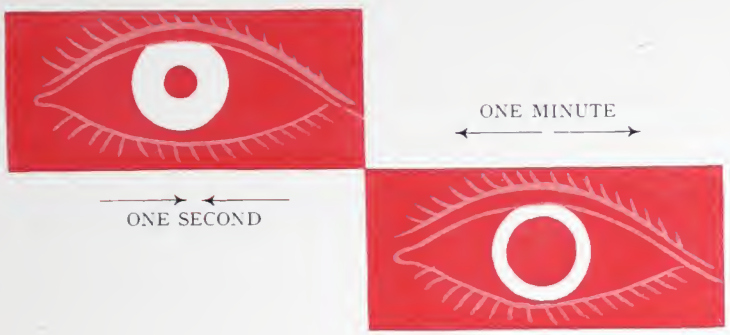
The simple graph above illustrates this in another way. To perceive the mere presence of a black dot on a white background, the simplest act of seeing that is possible requires three and one-half times as long under 2 foot-candles as under 100 foot-candles illumination, and twice as long at 2 foot-candles as at 20.

At usual levels of industrial lighting intensity (3 to 5 foot-candles) the astigmatic eye requires twice as much time to perceive as the normal eye—and the significance of this fact is that possibly half of all human eyes have some degree of astigmatism.

Time-exposure seeing is fatiguing both for good eyes and poor. Eye strain causes uneasiness, drowsiness and general slowing down in production.

Good lighting, on the other hand, is a psychological stimulus quite apart from its direct effect of increasing acuity, speed of discrimination and power to sustain clear seeing over extended periods of work.

How glare and shadow slow up seeing and waste workers' time . . . .



THE contracting of the iris or pupil of the eye to protect the sensitive retina from temporary blindness takes place in a second, but the expanding of the pupil takes sixty times as long.

Light sources which are too low or which throw light directly into the eye are the chief sources of glare. The worker looks up, and the pupil contracts suddenly. A second later the eye is again directed to the working plane but the contracted pupil takes a minute to open up sufficiently for clear seeing.

In shops where glare and shadows abound, where the intensity of illumination differs widely within a few feet, or where a slight movement of the head brings low hanging light sources directly in the line of vision, this alternate contraction and dilation of the pupil can take place thousands of times a day. Multiply this by the number of employees and the amount of time wasted by eye adjustment, and the amount of eye strain and fatigue unnecessarily resulting, is appalling to contemplate.

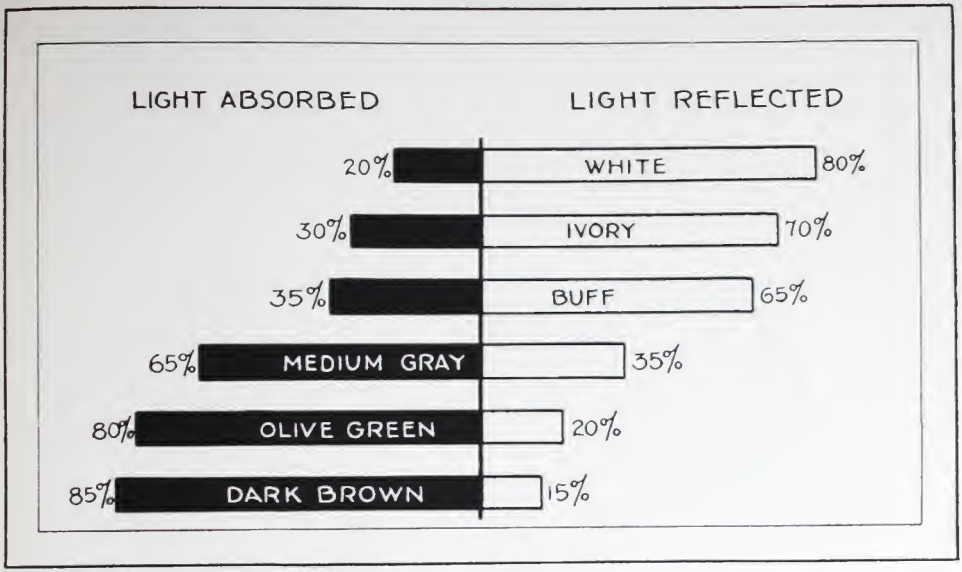
The redesigning of a factory lighting system so that it will eliminate preventable glare and shadow, is worth whatever it may cost.

How to get all the light you are paying for anyway . . . . .

THE most modern type of factory lighting system properly installed will seldom cost as much as 2½ per cent of the payroll. This figure includes amortizing the equipment over a period of six years and all elements of overhead and operating cost. In many cases excellent lighting costs only one per cent, and almost never two per cent of production expense.

As such a system will invariably increase production, or lower costs and will reduce spoilage, lessen labor turnover and accidents, all of which are profit factors, good lighting is always a good investment.

Once installed, the intent of management naturally is to keep the system at a high level of efficiency. Efficiency, however, depends upon alertness in maintenance not only of the actual lighting equipment, but to an equally important degree, of all of the surroundings.



By painting the walls and ceilings white or cream, machinery gray with a semi-mat or mat glossy finish, by getting rid of all possible dark or light-absorbing surfaces, it is often possible to raise the level of illumination by 50 to 100 per cent without increase of wattage. This is using the same light twice or three times.

The judicious use of paint to increase reflection and reduce absorption will go a long way toward softening shadows and reducing glare.

Dirty reflectors and lamps will waste as much as 80 cents out of every dollar's worth of electric current and lamp life that you buy.

Regular cleaning, using soap and water as well as wiping regularly, pays handsome dividends in industrial lighting. Proper layout and selection of equipment will go far to facilitate maintenance.

The proper size and shape reflectors are important. Using 1000 watt lamps in 500 watt reflectors is not economy—it is extravagance.

It doesn't pay to use lamps till they die of old age . . . . . .

LAMPS of good quality to start with are lamps which yield the highest average efficiency during their life. Poor quality lamps may show a high light output when new, but due to inherent characteristics, the light output falls off rapidly and they produce less total light than lamps of standard quality.

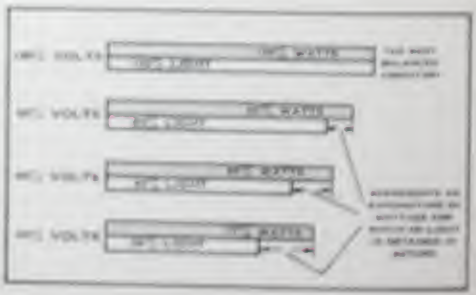
There is no economy in using lamps which, though still yielding light, have gone long past their normal life.

Too low or too high voltage is another source of lighting waste. Too low voltage (due usually to too long a circuit or overloaded circuits) lessens light output. Too high voltage shortens the life of the lamp.

A drop of 5 per cent in voltage will cause a drop of 17 per cent in light output, and though wattage is reduced, the loss in light is so much greater that the unit cost of light is considerably increased.

Voltage drop should not be over 2 per cent from switchboard to socket. Oversize wiring will reduce voltage drop and is a good investment. No branch circuit should be over 100 feet long.

Don't starve your lighting system with insufficient voltage



Foot-Candle Meter, the Sherlock Holmes that shows up lighting culprits . . . .

LIGHTING considered as a tool for seeing and as an important factor in production, should be checked up from time to time so that its maintenance at the efficiency level can be assured.

The simplest method for gauging the intensity of illumination (and thereby keeping it at the pre-determined standard for all processes and locations in the plant) is the periodical use of an instrument called the foot-candle meter.

The foot-candle meter is an inexpensive intrument, easily obtainable, and sturdy enough for everyday use. It tells the foot-candle illumination existing at any spot, by mere inspection of a scale of round dots. Anyone can learn to use it with only a minute or two of simple instructions, and the principle of its operation is so simple that the moment it is pointed out it is understood.

What would a foot-candle meter show in your plant? If you have never had a check-up made with its help, you will have many surprises. Do you know whether you are trying to get along with two or three foot-candles where 15 or 20 would result in better seeing and better production? Are you aware of places where safety calls for several times the illumination you are providing? Are you, perhaps, affording some workers several times as much light for seeing as you are others on the same kind of work—yet expecting equal efficiency from all? These and many other important questions can be quickly answered with a foot-candle meter.

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